Web-based autism screening using facial images and convolutional neural network

Mohamed Ikermane[1], Abdelkrim El Mouatasim[2]
[1]Laboratory LABSI, Faculty of Sciences, Ibn Zohr University, Agadir, Morocco
[2]Department of Mathematics and Management, Faculty of Polydisciplinary Ouarzazate (FPO), Ibn Zohr University, Ouarzazate, Morocco

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ABSTRACT

Developmental disabilities such as autism spectrum disorder (ASD) affect a person's ability to interact socially, and communicate effectively and also cause behavioral issues. Children with ASD cannot be cured but they might benefit from early intervention to enhance their cognitive abilities, favorite their growth , and affect their lives and families in a positive way. Multiple standard ASD screening tools are used such as the autism diagnostic observational schedule (ADOS) and the autism diagnostic interview (ADI), which are known to be lengthy and challenging without specialist training to administrate and score. The process of ASD assessment can be time-consuming and costly, and the growing number of autistic cases worldwide indicates an urgent need for a quick, simple, and dependable self-administered autism screening tool that may be used if a child displays some of the common signs of autism, and to ensure whether or not he should seek professional full ASD diagnosis. According to a number of studies, ASD individuals exhibit facial phenotypes that are distinct from those of normally developing children. Furthermore, convolutional neural networks (CNN) have mostly found utility in image classification applications due to their high classification accuracy. Using facial images, a dense convolutional network (Densenet) model, and cloud-based advantages, in this paper we proposed a practical, fast, and easy-to-use ASD online screening approach. Easily available through the internet via the link "https://asd-detector.herokuapp.com/", our suggested web-based screening instrument may be a practical and trustworthy tool for practitioners in their ASD diagnostic procedures with a 98 percent testing dataset classification accuracy.

Corresponding Author:

Mohamed Ikermane
Laboratory LABSI, Faculty of Sciences, Ibn Zohr University
BP 32/S, Riad Salam, CP 80000, Agadir, Morocco
Email: ikermane.mohamed@gmail.com

1. INTRODUCTION

Autism spectrum disorder (ASD) is a term that refers to a developmental disability due to a range of complex neuro-developmental differences, and that may create considerable difficulties in social interaction, communication, and child behaviors [1], [2]. Signs of autism spectrum disorder are evident from early infancy and remain throughout life living, impacting youngsters as well as their families [3], [4]. Autism symptoms are more obvious and simpler to recognize in children between the ages of 2 and 3 years old [5]. Inadequate social-emotional reciprocity and diminished communicative non-verbal behaviors utilized for social engagement are two of the most intense signs of this condition. Nevertheless, diagnoses of ASD may be made as early as

18 months of age [6], [7]. When diagnosing ASD, doctors must do a clinical evaluation of an individual's developmental age, which is based on a range of factors, such as their behavior excesses, communication difficulties, self-care, and social abilities [8], [9]. Multiple tools may be used by diagnosticians throughout the process of ASD assessment, such as the autism diagnostic observational schedule (ADOS) [10], which is appropriate to diagnose children aged from 12 to adults, and the autism diagnostic interview-revised (ADI-R) that focus on assessing child's social interactions, communication, and language [11]. Using and scoring any of those screening instruments is a time-consuming task and difficult without specialized training.

Many studies have focused on automating ASD identification by employing deep learning algorithms, and substituting scoring techniques in standard ASD screening approaches. Sherkatghanad *et al.* [12] employed a convolutional neural network to construct an automated autism screening tool based on a dataset called autism brain imaging exchange (ABIDE), in which they used functional magnetic resonance imaging (fMRI) to predict ASD subjects with an accuracy of 70%. The VGG16 deep learning algorithm was applied to an ASD facial images dataset of clinically diagnosed children by Lu and Perkowski [13], their convolutional neural network model performed with an accuracy of 95%. They used facial images to predict ASD presence in children based on many clinical studies that demonstrate there are face phenotypic differences between ASD children and normally developing (TD) children [14]. Recent studies have shown that there is a distinct difference in the facial characteristics of an autistic Child. those with ASD have face morphology that is unique from typically developing children, and two-dimensional facial measures are a predictor of the prevalence of ASD in children, according to studies conducted by Aldridge *et al.* [14] and Obafemi-Ajayi *et al.* [15]. They both confirmed that regardless of the distance measurement employed respectively euclidean and geodesic that compared to a typical child, autistic children have considerably more facial morphological abnormalities. A web-based screening tool for autism spectrum disorder (ASD) using facial images is the focus of this work, which intends to provide a rapid and easy-to-use ASD assessing alternative tool, that is built on a well-trained dense convolutional network (Densenet) model using an optimizer called the control sub-gradient algorithm (CSA) [16], which update the learning rate by a control step in each iteration of each epoch. Also, to make it widely accessible this tool was developed using the Python web framework Django [17] and deployed online to the cloud platform Heroku [18].

2. MATERIALS AND METHODS

2.1. CNN Densenet model

With the use of convolutional neural networks (CNN), images may be accurately classified. There are several types of CNN. In this particular work, we used the Densenet algorithm [19] that uses dense connections between layers using Dense blocks, which link all layers directly to each other. Feeding forward is maintained by obtaining new input from all previous layers and passing on their own feature maps to the next ones. As illustrated in Figure 1 every layer (Dense block) has the feature maps of its preceding layers and of the input layer concatenated, each layer is then adding new information and then passe it as an input to the next layer.

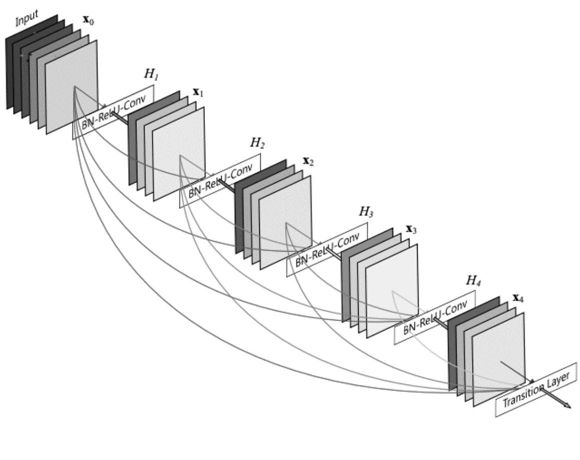


Figure 1. Convolutional Densenet network structure

2.2. Control subgradient algorithm optimizer

The weights and learning rate of a neural network may be adjusted using a neural network optimizer. As a result, it reduces the overall loss and improves accuracy. During the training phase, the weights of the Deep neural network model are continuously modified to lower the output error compared to the predicted output using the optimization function. For classifying images, a subgradient method variant that has being used in an earlier work [16] performed quite well. The control subgradient algorithm (CSA) Optimizer uses a control step in each iteration of each epoch and adjusts the learning rate accordingly.

2.3. Autism facial images dataset

As Figure 2 illustrates, in an ASD child's facial morphology compared to a normal child the length of the white lines is longer, whereas the length of the black lines is shorter. The proposed CNN Densenet model was trained on the publicly available Kaggle Autism face pictures dataset [20] using Pytorch [21] on a PC running Windows 10 with an Intel Core i7 8^{th} generation processor and 16 gigabytes of RAM. The ASD dataset was first cleaned by removing duplicates images and those for too young children, and then divided as indicated in table 1, into three sections: train (80%), test (15%), and validation (5%). Each section had two sub-folders: autistic and non-autistic. Pictures have been cropped to display just the child's face, regardless of their different size. Children ranging in age from 2 to 14 years Figure 3.

Figure 2. Autistic child facial morphology characteristics

Table 1. Autism facial images dataset splitting into 3 subsets

	Train	Test	Valid	Support
Autistic	1154	216	72	1442
Non autistic	1164	218	73	1455
				2897

Figure 3. Facial images dataset sample

2.4. Web-based tool structure

Individuals with autism spectrum condition and their families may greatly benefit from early diagnosis and treatment [22]. That being the case, the purpose of this work is to offer an easy-to-use diagnostic tool that may be used by practitioners to quickly and accurately diagnose subjects suspected of having any indicators of Autism spectrum disease like avoiding eye contact and avoiding physical contact [23]. Our web-based ASD screening tool just requires a connected device and a clear facial picture of the diagnosis subject. Figure 4 displays the home page where the user may learn more about our ASD screening approach and CNN Densenet model by pressing the link “Click Here” or immediately start the assessment using the button below “Begin Test”.

Figure 4. Home page of the web-based ASD screening tool

Due to its quick production of safe and maintainable websites that allow access to deep learning applications to be widely disposable, the Python-based web framework Django has recently been heavily employed in several domains such as health care [24] and intelligent system management [25]. The Django framework version 4.0.4 was used to build this platform, which was then deployed utilizing the Heroku platform, which allows developers to run and manage web applications fully in the cloud. Our CNN Densenet model, which uses facial images to predict ASD, may be easily and universally interacted with through this online interface. Figure 5 shows the page’s structure of our ASD web-based screening tool.

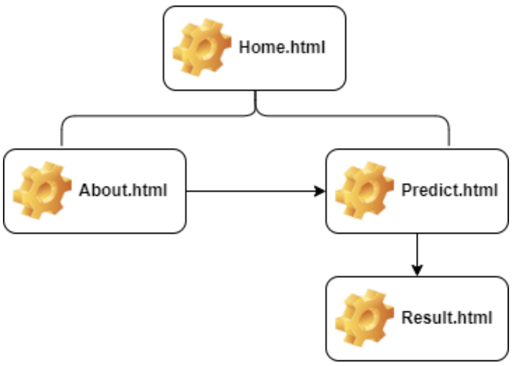


Figure 5. ASD screening tool website page’s structure

2.5. ASD image screening processes

Figure 6 depicts the steps involved in using the web-based ASD screening tool. First, a user must access the website at the URL “https://asd-detector.herokuapp.com.” Next, a facial image of the diagnosed child is uploaded via the web page predict.html to the Heroku cloud platform to be processed by our CNN Densenet model. This is done after the image has been pre-processed by resizing the image and then normalizing it. Following that, the classification, as well as the prediction probability, are sent to the user by means of the web page “result.html”.

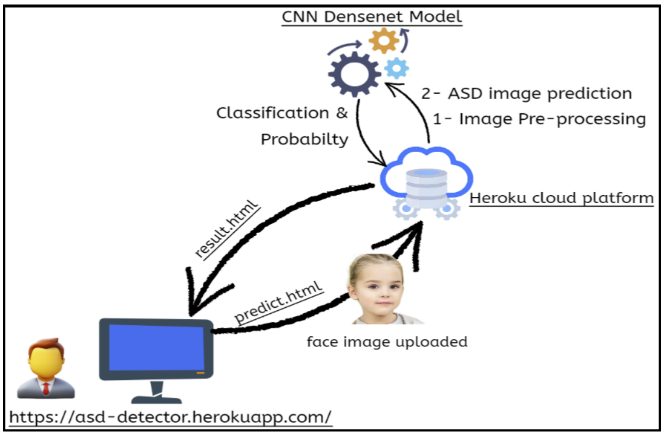
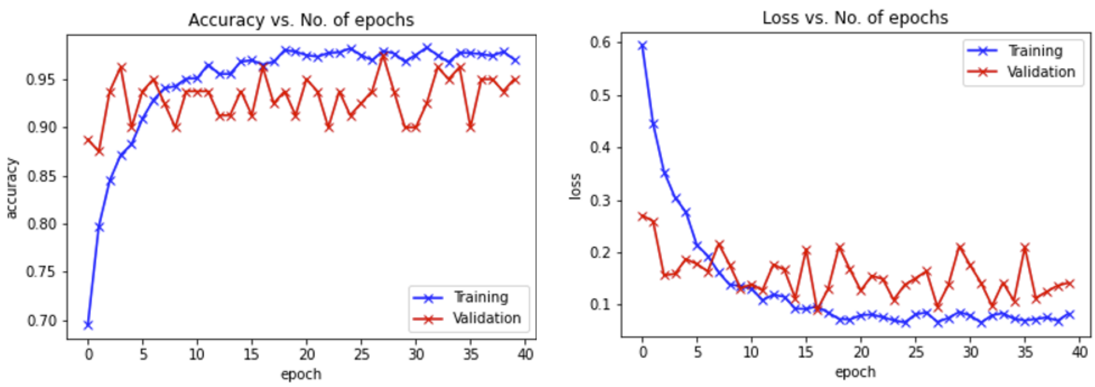


Figure 6. ASD image prediction processes using web-based screening tool

3. RESULTS AND DISCUSSION

As illustrated in Figure 7, The optimization learning curves at the start of the epochs, training and testing loss were quite considerable, but the accuracy of their performance curves was poor as shown in Figure 7(a) and Figure 7(b). The CSA optimizer updated the weights in each iteration of each epoch, allowing the model to learn quickly, such that after 10 epochs, the loss value gradually decreased and the accuracy considerably improved. Continuing model learning in the remaining epochs. In classifying autistic children using their facial images, the suggested CNN model achieved a training accuracy of 99.6. Evaluating our CNN Densenet model accuracy on the test data, we were able to achieve a 98% accuracy rate, as shown in the classification report Table 2. To visualize and summarize the performance of our classification CNN model. The confusion matrix Figure 8 below illustrates how well our model predicted the 434 facial images included in the test data.



(a) (b)

Figure 7. Learning curves of train and validation data (a) performance and (b) optimization

Table 2. CNN Densenet classification report

	Precision	Recall 3	F1-score	Support
Autistic	0.981	0.977	0.979	216
Non autistic	0.977	0.982	0.979	218
Accuracy	0.979			
Precision	0.977			
Recall	0.982			
F1-score	0.979			

Parents and medical practitioners may swiftly use our online ASD screening tool to diagnose a kid by submitting a picture of the diagnostic subject that is at most 14 years old on the predict web page "https://asd-detector.herokuapp.com/predict/." Using our trained Densenet CNN model, which we deployed on the Heroku cloud, the ASD screening application can determine if the child has Autism symptoms based on his or her facial characteristics or not. The more the picture shows clearly his face, the more the model can be accurate in classifying the subject. As shown in Figure 6, our ASD screening tool also gives the prediction probability indicating how sure our proposed model of this prediction is Figure 9. In order to monitor the use of our online ASD screening tool, we have included an administration panel into which we are able see information about every prediction (time, result,and probability). This admin panel allows also to sort and filter the results as illustrated in the Figure 10.

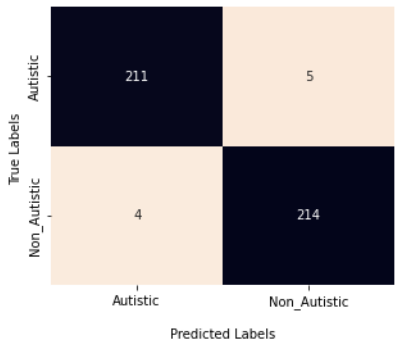


Figure 8. Confusion matrix of ASD facial image prediction

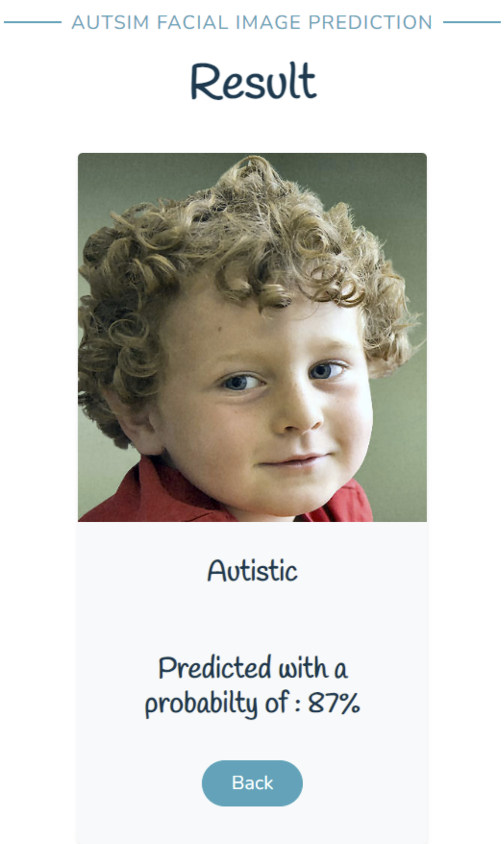


Figure 9. ASD online screening tool result page

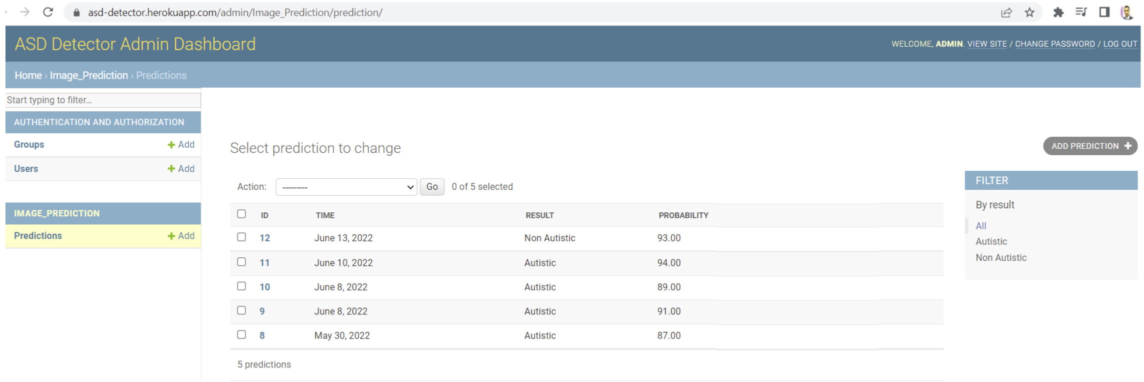


Figure 10. Online ASD screening tool admin panel

4. CONCLUSION

In this paper, we presented an online solution for ASD using CNN techniques via CSA optimizer, our proposed Densenet model used facial characteristics to predict ASD presence in a child, with a very good accuracy of 98% and an easy online access, a doctor or a practitioner may use this tool in the diagnosis phase of their subjects just by uploading a clear image of the child's face. Our screening model can classify images of children and distinguish between autistic and non-autistic children. Such an online ASD detection tool can be a vital asset for decision-makers in the ASD diagnosis process, and may also significantly enhance the quality and efficacy of their judgments.

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BIOGRAPHIES OF AUTHORS

Mohamed Ikermane is a PhD student member of Engineering Science Laboratory at Faculty of Sciences-Ibn-Zohr University, Morocco. With a master in distributed systems computing at Faculty of Science-Ibn Zohr University, Agadir (2014). He obtained Bachelor Degree in computer science at Polydisciplinary Faculty of Errachidia. He works as IT teacher at Regional Center for Education and Training Professions in Guelmim, Morocco. Recently, He works on Autism Detection Using Deep learning techniques. He can be contacted at email: ikermane.mohamed@gmail.com.

Abdelkrim El Mouatasim Is a Full Professor (PES) Faculty Polydisciplinary Ouarzazate, Ibn Zohr University, Morocco Coordinator of SMI (Mathematical and Computer Sciences) President of the Moroccan Association of Artificial Intelligence Representative of UNESCO's Member States (Morocco) for Recommendation on the Ethics of AI.His work is Numerical analyses and Optimization, Operation research, Mathematical modeling and statistical modeling, Stochastic Processes, Algorithms, programming and Computer simulation, Image processing, Data mining, data science and big data, Machine learning and deep learning. He can be contacted at email: a.elmouatasim@uiz.ac.ma.